General

Bonneville Power Administration (BPA) contracted MWH and GEI Consultants, Inc. (together identified as MWH hereafter) to review EPA's March 2001 report regarding the development of a Columbia River temperature model. The report, dated July 2002, is titled "Review of a 1-D Heat Budget Model of the Columbia River System". The MWH report represents BPA's second grant to one of the firms (Harza) to review the thermal energy budget model used by EPA Region 10. The first BPA-funded report, entitled "A Review of EPA Region 10 Columbia River Temperature Assessment Simulation Methods" dated September 1999 covered the same material as the present report, although in a much more objective and ultimately helpful manner. The first BPA-funded Harza review was one of several peer reviews of EPA"s temperature model. EPA responded to all reviews, including the first BPA-funded Harza review, as required by EPA's peer review policy. All responses were made part of the public record. More importantly, these reviews (including the first BPA-funded Harza review) provided constructive criticisms that have resulted in what EPA believes to be improvements in the temperature model as used in the Columbia River temperature TMDL

BPA has not formally delivered a copy of the MWH's most recent BPA-funded review of EPA's Columbia River temperature model to EPA Region 10. Reference to it first appeared in a letter to EPA Region 10 dated ?????? and signed by BPA's Director, _____ Fox. EPA's responses to the original BPA-funded report are relevant to the second BPA-funded report, since the material covered by the BPA-funded reviewers is essentially the same in both reviews.

However, EPA has completed additional work since March 2001 related to the Columbia/Snake River mainstem temperature TMDL In the interests of helping BPA understand EPA Region 10's temperature TMDL for the Columbia/Snake River system, we provide responses to the second BPA-funded review of EPA's temperature analysis. Two documents of particular importance in the administrative record for this project are the Problem Assessment and Preliminary Draft TMDL (see EPA Region 10 website). Several topics raised by MWH (water quality standards) are addressed in more depth in these recent documents.

EPA is surprised that MWH makes almost no reference to the degree to which the RBM10 model estimates correspond to observed mainstem temperatures, which is the first benchmark for evaluating the performance of a water quality model. A reader of the first 45 pages of highly critical MWH comments might conclude that the RBM10 model cannot possibly provide reasonable estimates of temperature in the Columbia and Snake Rivers. It is not until MWH is describing the application of a different one-dimensional heat budget model, MASS1, that it briefly notes that both models show general agreement between simulations and observations (Pg. 47).

The following are responses to the specific comments made by MWH in its review.

Water Quality Standards

MWH states that the EPA model focuses on the number of exceedances of the "existing standard of 20 °C". EPA did evaluate the number of exceedances of a 20 °C benchmark, but the report is not an evaluation of water quality standards violations. Furthermore, the report makes it clear that the use of the 20 °C benchmark is not meant to be viewed as "a surrogate for water quality criteria or as part of an ecological risk analsysis".While 20 °C is one of the numeric criteria applicable to a portion of the Columbia River, the water quality standards for Oregon and Washington include narrative requirements along with numeric criteria. EPA has evaluated the standards in subsequent documents in support of the TMDL (see EPA TMDL website).

Upstream Water Temperature

MWH asserts that EPA does not acknowledge that "upstream water is often the strongest predictor of downstream temperature." EPA's report is quite clear in defining the model boundaries and assumed inputs, and the assessment is explicitly focused on the effects of those mainstem dams below the model boundaries on river temperature. Model simulations of the "impounded" and "unimpounded" conditions use the same upstream boundary temperatures; therefore, differences in temperatures for the two cases incorporate the effect of upstream temperatures.

Data Quality

MWH complains that EPA's data is inadequate, noting the EPA admits that data quality varies considerably across the basin. First, it should be noted that none of the data used in the model development was collected by EPA. Rather, the EPA analysis rests on information collected by numerous agencies including the U.S. Army Corps of Engineers, Bureau of Reclamation, National Weather Service, U.S. Geological Survey, and the state environmental agencies. EPA does not have the responsibility or the resources to collect the vast quantity of data used in this model. Furthermore, it should be noted that EPA Region 10, as an active participant in the Water Quality Team and the RPA 143 sub-group, has been an advocate of improved quality control measures for data collection on the Columbia. We believe that this advocacy has played a major role in (1) recognition of the shortcomings of some data collection methods and (2) improvements in quality control procedures used to measure and report environmental data for the Columbia River.

While analysts should strive to identify and reduce measurement and model error to the extent possible, error and uncertainty are a fact of life. EPA strongly disagrees with the implicit suggestion in MWH's criticisms that the data quality problems are so great that no analysis should be undertaken. Most environmental assessment work, including water quality model development, requires the use of information collected in the past. In a system the size of the Columbia basin, with no data collection strategy for temperature state estimation, the variability in data quality is to be expected. EPA has identified issues in data collection and minimized the variance in modeled and measured temperatures for a 30-year record. MWH does not offer concrete suggestions for improving model performance.

Effects of Reservoirs on Temperature

MWH states that EPA has assumed that all reservoirs are likely to affect temperature similarly, and that MWH analysis shows that the variety of depths, lengths, widths, and gradients of the reservoirs would each produce different surface-to-volume ratios and thermal behavoir if removed. EPA's model explicitly accounts for the varying geometry of the river and impoundments, so it is inaccurate to portray EPA's analysis as assuming that all reservoirs affect temperature similarly.

1-D Model

MWH asserts that the assessment of "homogenous" or cross-sectional average temperatures, the "measurement bias" of the model, and the assessment of exceedance only (not magnitude of the exceedance) make the assessment results a poor indicator of impacts to salmon. EPA believes that RBM10 provides reasonable, one-dimensional temperature estimates at the basinwide scale, and the model has provided valuable information about the effects of river management on temperature. At the same time, two-dimensional analysis may provide additional insights into temperature regimes within the more stratified reservoirs. For this reason, EPA continues to evaluate two of these reservoirs (Lower Granite and Grand Coulee) using the CE-QUAL-W2 model. EPA believes both one- and two-dimensional analysis is relevant to salmon health.

Effect of Tributaries

MWH uses a simple hypothetical example to suggest that EPA's use of a fixed benchmark (20 °C) for evaluation conceals the true effects of tributaries, and that EPA "implies that we should abandon improving thermal TMDL's in our tributaries, a conclusion most would be surprised as coming from EPA." Tributary impacts were explicitly evaluated over a long term simulation. Given the voluminous estimates provided by the model (daily values for a 30 year period), including estimates of temperatures near the benchmark value, it is reasonable to expect the number of exceedances of the benchmark to change significantly if the tributary effect was significant. EPA estimated the change to be minor and appropriately reported this finding. Nowhere in the EPA report is there a suggestion that projects to improve tributary temperatures should be abandoned.

Steady vs Unsteady Flow

MWH makes brief reference to EPA's use of gradually-varied flow methods when the river "is actually an unsteady flow". MWH fails to provide any additional information indicating that use of unsteady flow hydraulics improves heat budget model performance for this river system. Given the consistent performance of RBM10 under a variety of conditions, including highly variable flow augmentation periods on the Snake River as well as more recent tests on the unregulated Fraser River in British Columbia, EPA believes that the cost of adding the complexity of unsteady flow hydraulics to model set-up and operation outweighs the limited benefit (if any) to simulation results. The same can be said for MWH's concerns that the model does not include longitudinal dispersion. Given limited assessment resources, EPA's goal is to develop models that are as simple as possible yet captures the predominant drivers of system variability at the length and time scales of interest.

Meteorological Data Substitution

MWH states that it found that some of the wind speed and vapor pressure data are duplicated between stations, implying a mistake in the construction of input files. MWH fails to note that this duplication was an intentional step taken to improve meteorological data coverage, and EPA documented the assumption that these two parameters were regional phenomena in the report (Pg. 35 of EPA report).

MWH then states that the duplicated data must be carefully screened to remove the estimated 5% of cases where MWH discerned physically impossible conditions in the dataset. EPA believes that editing the data sets to eliminate a small number of physically impossible data pairs will not remove the uncertainty in the data nor necessarily improve model performance. EPA notes that overall model performance is reasonable despite the input data uncertainties, including uncertainties in the meteorological dataset.

Evaporation Assumptions

MWH states that EPA's assumption that the evaporation rate is equal in both existing and free-flowing river scenarios is flawed. EPA believes that this is a reasonable assumption but recognizes the uncertainty of this assumption. A plausible alternative would be to assume that evaporation is greater in the free-flowing river due to higher velocities and turbulence (how much greater is guesswork). This would result in cooler simulated temperatures for the free-flowing river.

MWH states that the application of a 1-D model to stratified impoundments over-estimates the evaporation rate and therefore exaggerates the difference between free-flowing and impounded river temperatures. They note that a stratified impoundment has a higher evaporation rate than it would if it were completely mixed, as assumed in one-dimensional analysis, since the surface temperature for the mixed river would be lower. MWH then states "If this condition is not accounted for...the resulting deduced cooling rates would tend to be over estimated". This is correct, because the greater cooling of the heated surface layer would be reflected in lower tailrace temperatures than would be calculated by the 1-D model. This would necessitate an increase in the 1-D evaporation rate to match tailrace temperatures. MWH then goes on to assert that this 1-D evaporation rate exaggerates the effect of impoundments on the free-flowing river. MWH fails to note that the degree of over-prediction is directly tied to the degree of stratification of the waterbody. In this system, the differences between surface temperatures and cross-sectional average temperatures are generally minor due to the run-of-river configuration of the dams.

MWH continues with the assertion that the estimated evaporation rate "would yield a conclusion that the river cooling rates were disproportionately high and that the original reservoir cooling rates were disproportionally low. Such bias would of course exaggerate the beneficial attributes of a natural river (no reservoirs) and underestimate the cooling potential of a reservoir". First, the estimated evaporation rate does not bias the simulations of the impounded condition at all, because the rate is estimated using measured temperatures. Second, EPA believes any difference in the evaporation rate would be minor in these minimally stratified impoundments. Finally, evaporation in all likelihood would be somewhat higher in riverine than impounded conditions.

MWH concludes with a suggestion to express evaporation rates as functions of instantaneous water temperatures, air temperatures, barometric pressures, wind speeds, and humidity. RBM10 calculates net evaporation based on these variables and the evaporation rate (which is an empirical constant) at each time step. MWH suggests a variable rate but provides no suggested approaches or literature sources to accomplish this task. EPA welcomes additional research in this area, but in its absence, reiterates that the model provides reasonable estimates with a constant or seasonal rate.

RBM10 and MASS1

MWH includes a chapter entitled "Review of Alternate Models that Might be Applied to the Issue" and then proceeds to describe only one alternate model, Batelle's MASS1 model. This review is breathtakingly short (3 pages) and provides scant details about the similarities and differences between RBM10 and MASS1.

Since both are one-dimensional heat budget models with similar boundaries and available data, EPA would expect similar results from the two models. This appears to be the case as MWH states that both models predict temperatures to within 1.0 - 1.5 °C of measured temperatures, and both models predict a temporal shift in spring heating and fall cooling due to the impoundment of the river by hydroelectric dams.